



Case Study of Two MBCx Projects: Using M&V to Track Energy Performance

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Overview

This presentation will discuss:

- **Role of M&V in RCx**
- **Application in two UC Berkeley Buildings**
- **Results**
- **Discussion & Conclusion**

Situation

- RCx is a means to improve a building's energy efficiency
 - Owners
 - EE Programs
- “RCx Measures”
 - Correct and optimize system operations
 - Operational changes
 - Control system changes
 - Justification provided by measure cost-effectiveness
- RCx measure recommendations based on savings estimates

Situation

- RCx measure savings estimates are based on:
 - Design documentation
 - Equipment specifications
 - Monitored operational data
 - Independent data loggers
 - Control system trends
 - Bin models, engineering models, computer simulations, etc.
- Do savings estimates = “real” savings?
 - Model errors
 - Incomplete or inaccurate data
 - Incorrect assumptions
 - Etc.

Situation

Risks to Owner:

- Savings not delivered, no return on investment
- No ability to track actual savings
- Savings do not last:
 - “Soft” measures that can be and often are defeated

EE Program Risks:

- Program’s claimed savings do not stand up to third party review
- Savings lifetimes are short
- Negative impact on program realization rates



Need for Robust M&V in RCx Projects

Needs:

- Demonstrate actual, verified energy savings benefits of RCx
- Provide a mechanism to determine measure savings persistence

Opportunities:

- Standardization of M&V processes for RCx
 - California Commissioning Collaborative Project
- Provide information tools for operators and owners to maintain savings
- Basis for further energy performance improvements

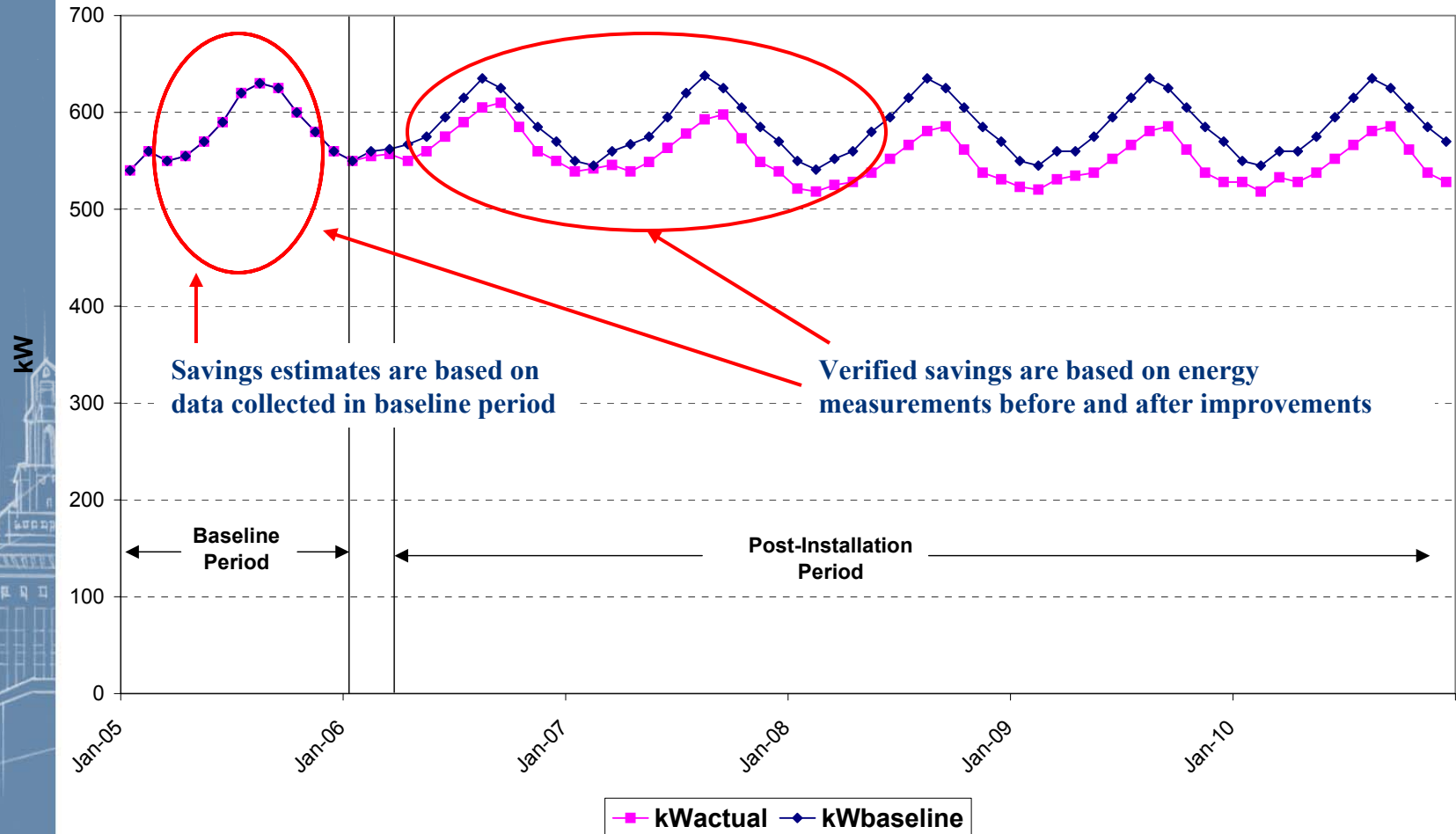
Basic M&V

International Performance Measurement and Verification Protocol (IPMVP) Chapter 3 says:

$$\begin{aligned} \text{Energy Savings} = & \text{Baseyear Energy Use} \\ & - \text{Post-Retrofit Energy Use} \\ & \pm \text{Adjustments} \end{aligned}$$

- **Baseline energy use is modeled**
- **Model generates what baseline use would have been under post-install conditions**
- **‘Adjusted baseline’ is compared with measured use to generate savings**

Quantifying Savings



IPMVP M&V Options

Retrofit Isolation Options:

- Option A: Allows stipulation of some parameters
- Option B: Retrofit isolation – continuous monitoring of parameters
 - Focus is on systems and equipment – similar to RCx.

Whole Building Options:

- Option C: Utility bill analysis
- Option D: Calibrated computer simulation
 - Sometimes used with isolated systems, as applicable
- Used when savings distinguishable from variation in use (typ. >15%)
- Option B selected for UC Berkeley
 - Magnifies savings as a proportion of use
 - + addresses savings persistence, provides tracking tools
 - Technique also applied at whole-building level

UC Berkeley MBCx Project

- UC Berkeley has significant monitoring resources to devote to this project
 - Web-based utility information system
 - Whole building kW and steam meters
 - Electric and steam trended at 15 minute intervals
 - Data stored indefinitely
 - Web-based points mapped from BAS
 - Chiller kW
 - BAS points trended at 1 minute intervals
 - Data stored for 6 months

Soda Hall

- UC Berkeley's Computer Science Department (24/7 operation)
- 109,000 ft²
- Energy Use Intensity: 174 kBtu/ft²-yr
- 2 - 215 ton chillers (lead/lag)
- Constant Speed Primary/Variable Speed Secondary Chilled Water System
- Two 2-speed, forced draft, open loop cooling towers
- 3 Main VAV AHUs,
 - AHU1 serves building core,
 - AHUs 3 and 4 serve the perimeter, with hot water reheat
- 11 computer room DX units, water cooled with variable speed pumps
- Steam to hot water heat exchanger, 2 variable speed HW pumps

Soda Hall RCx Findings

- **Minimum VAV Box Damper Positions at 50%**
 - Causes excessive reheat in perimeter zones
 - Little modulation of fan VFD
- **Several AHU VFDs broken or not modulating**
 - Return to designed VAV operation
 - Return to scheduled operation
- **Re-establish supply air temperature set point reset control in AHU1**
- **Other measures**
- **Approximately 483,000 kWh (10%), 2.7M lbs/yr steam (51%)**
 - Estimated using DOE2 analysis
- **Cost reduction \$84,000 (14%), Payback 0.7 years**

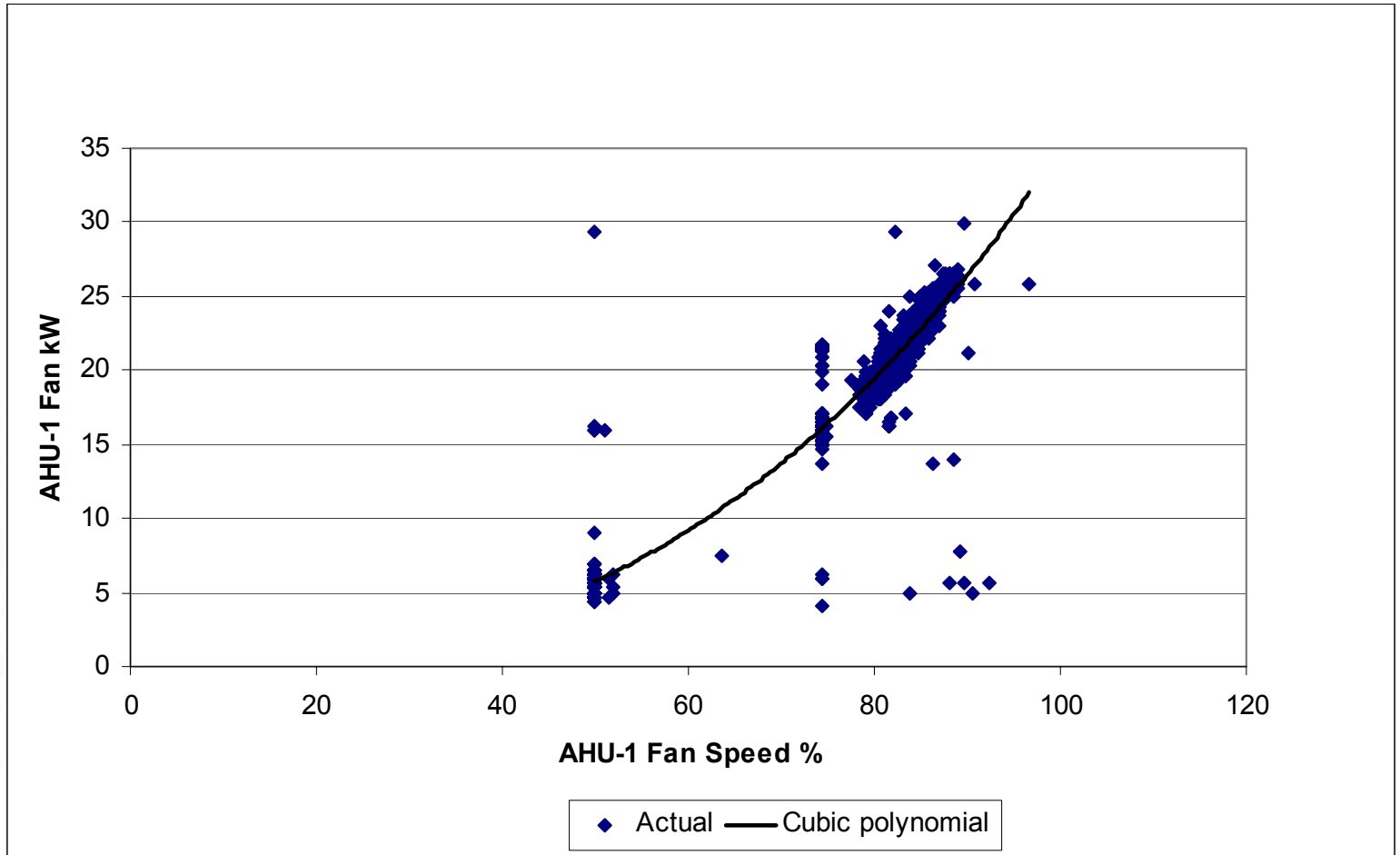
Soda Hall Affected Systems

System	Equipment	Affected by ECM?	Available Points
<u>Whole Building</u>		X	
	Main Electric Meters (2)		kW
	Main Steam Meters (2)		lb
<u>Chilled Water System</u>		X	
	Chillers 1 and 2		kW
	Primary Chilled Water Pumps P-5, P-6		Status
	Secondary Chilled Water Pumps, P-3, P-4		VFD speed
<u>Condenser Water System</u>		X	
	Cooling Towers		High/Low Status
	Condenser Water Pumps P-7, P-8		Status
<u>Air Distribution System</u>		X	
	AHU-1, SF-11, EF-12, EF-13		VFD speed
	AHU-2, SF-14, EF-15		Status
	AHU-3, SF-16, SF-17		VFD speed
	AHU-4, SF-18, SF-19		VFD speed
	AHU-5, SF-20		Status
<u>Chiller Room Fans</u>			
	Chiller Room 181, SF-2, EF-2		Status
	Chiller Room 179, SF-3A, SF-3B, EF-1A, EF-1B		Status
<u>AC Units</u>			
	Condenser Water Pumps P-9, P-10		VFD speed
	AC-31 through AC-41		Status
<u>Hot Water System</u>		X	
	Hot Water Pumps P-1, P-2		VFD Speed

Define the Baseline Period & Collect Data

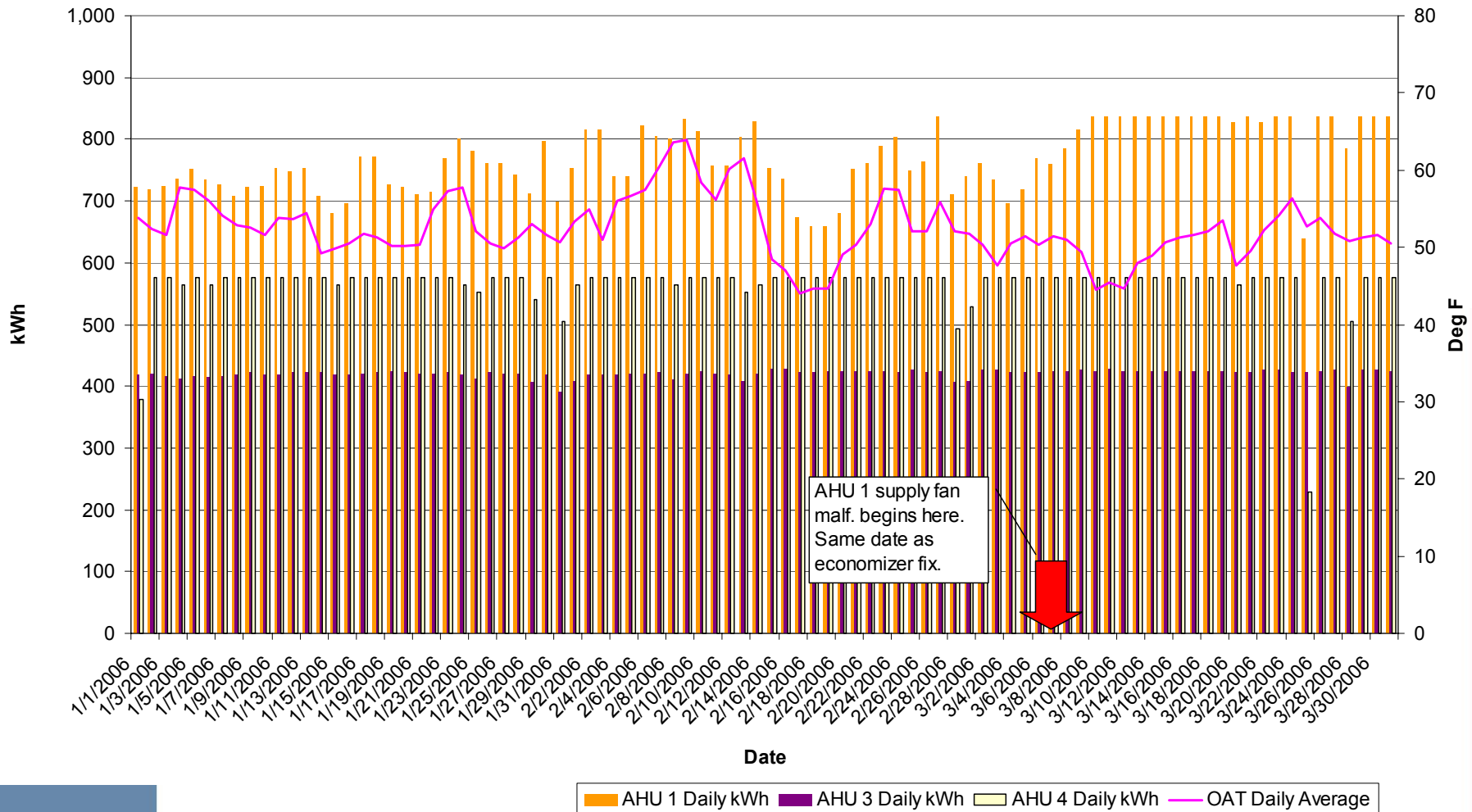
- 8 months of trended data collected
- Baseline period selected to cover widest range of operating conditions ~ 3 months.
- Energy use for each system to be totaled each day
 - Basis for analysis and reporting
- “Proxy” Variables on EMCS:
 - Constant load equipment: measure operating kW
 - Equipment status becomes proxy for kW
 - Variable load equipment: log kW and VFD speed
 - VFD speed signal becomes proxy for kW

“Proxy” Variable: VFD speed for kW



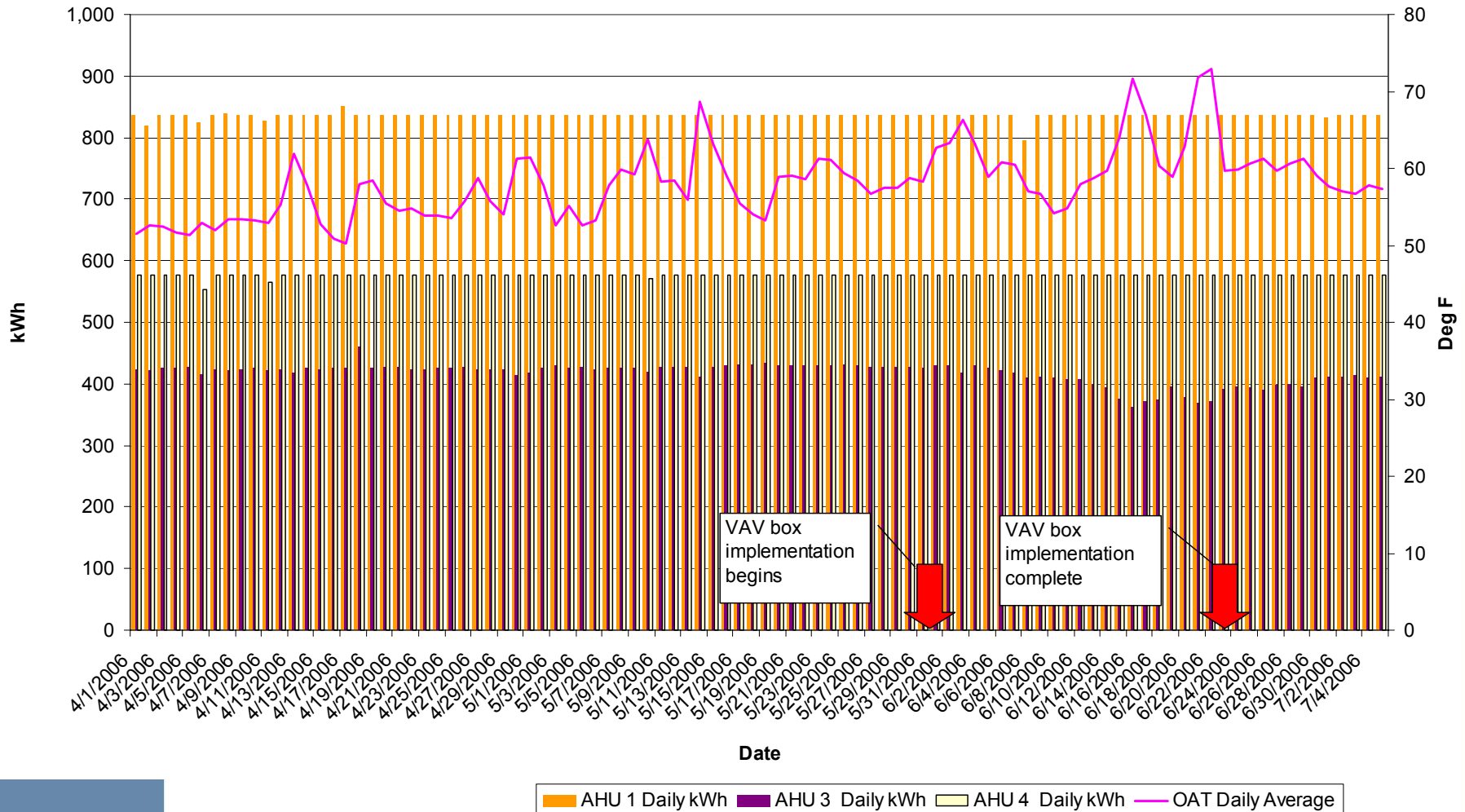
M&V “Diagnostics”

Soda Hall



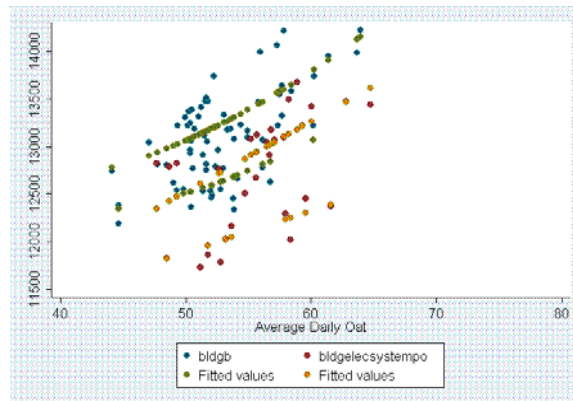
M&V Diagnostics

Soda Hall

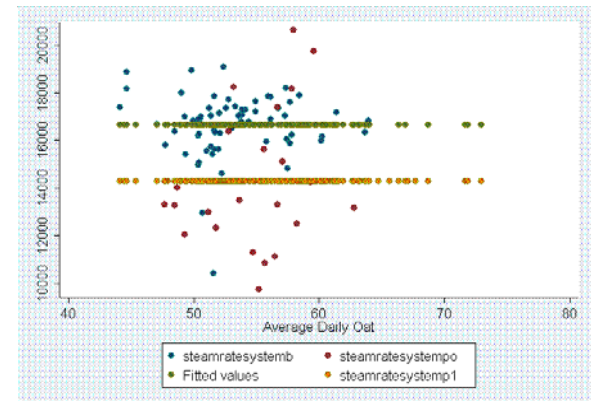


Baseline Model: Soda Hall

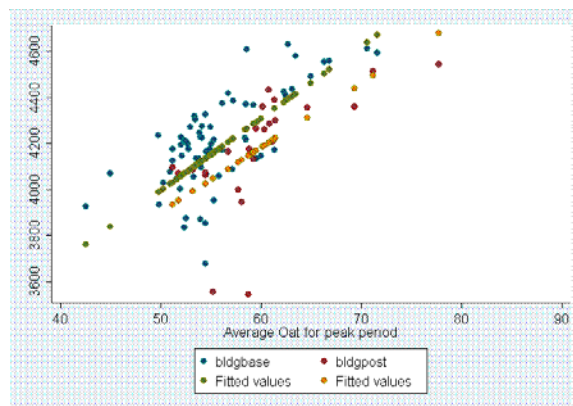
- **Total Building Electric**



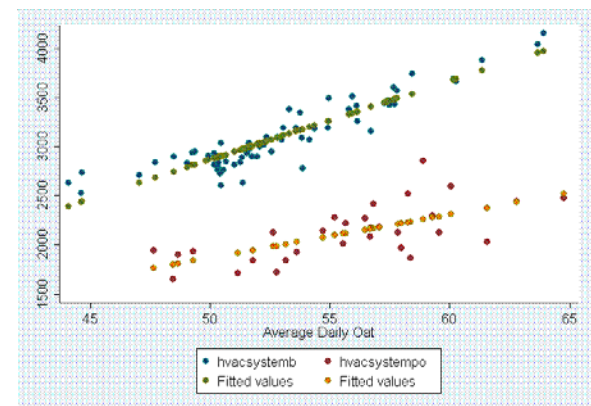
Building Steam



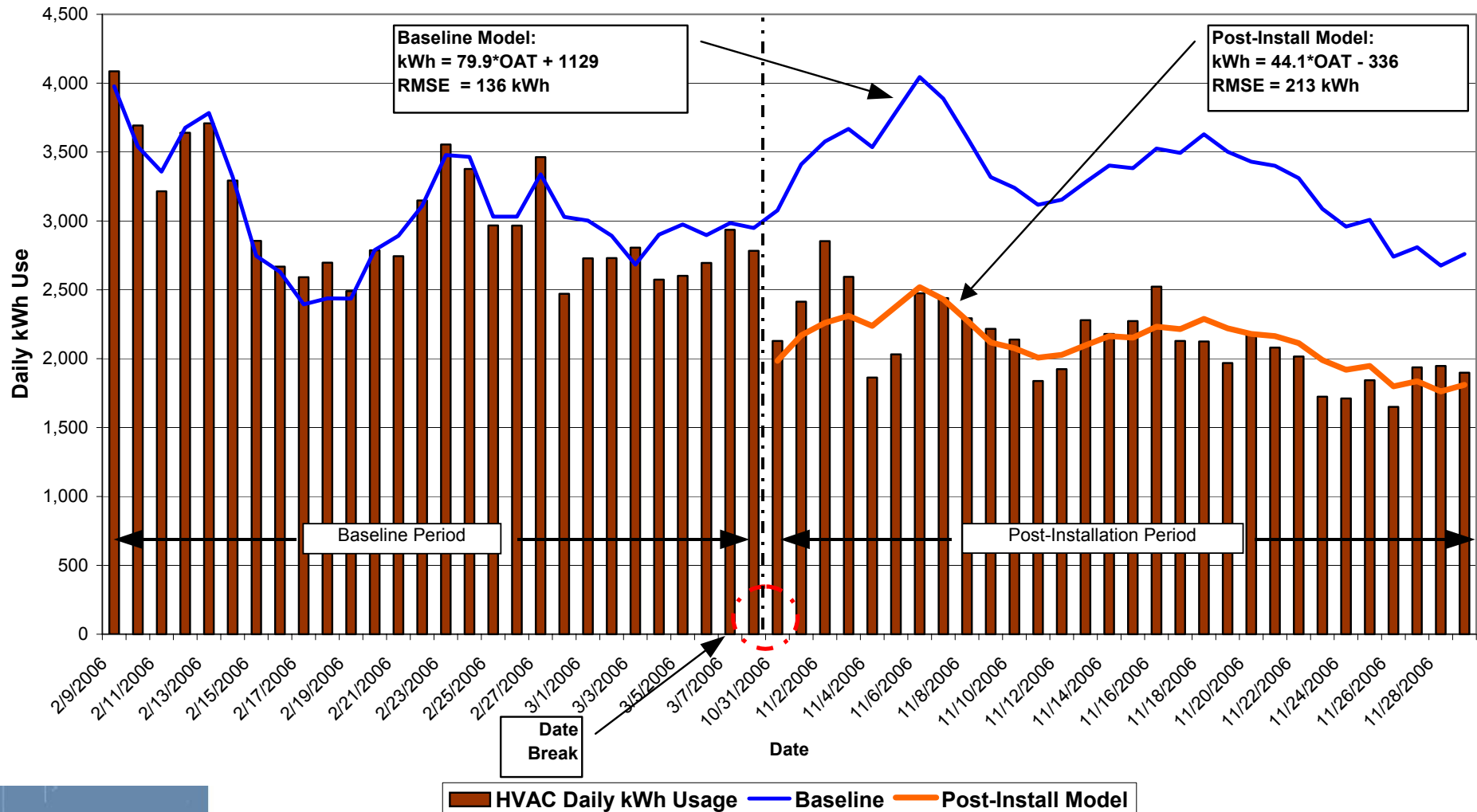
- **Peak Period Electric**



HVAC System Electric



Soda Hall M&V: HVAC Systems



Soda Hall: Estimated vs. Verified Savings

Source	Estimated Savings*	Verified Savings**	
		Whole Building	HVAC System
kWh	483,008	216,716	462,472
kW	-	22	50
Lbs. Steam	2,713,650	854,407	

* based on eQUEST model

** based on baseline and post-installation measurements and TMY OAT data



Tan Hall

- UC Berkeley's Chemistry and Chemical Engineering Departments
- 7 above-grade, 2 below-grade levels
- 106,000 ft²
- 100% outside air through 4 VFD-controlled 100 HP supply fans
- Steam heating and CHW cooling coils in AHU
- Separate exhaust system on roof: 4 VFD-controlled 60 HP exhaust fans
- 1 475-ton chiller, constant speed primary loop
- Constant speed CW loop – Tower shared among buildings
- Steam-to HW HX system, circulated to perimeter zone boxes

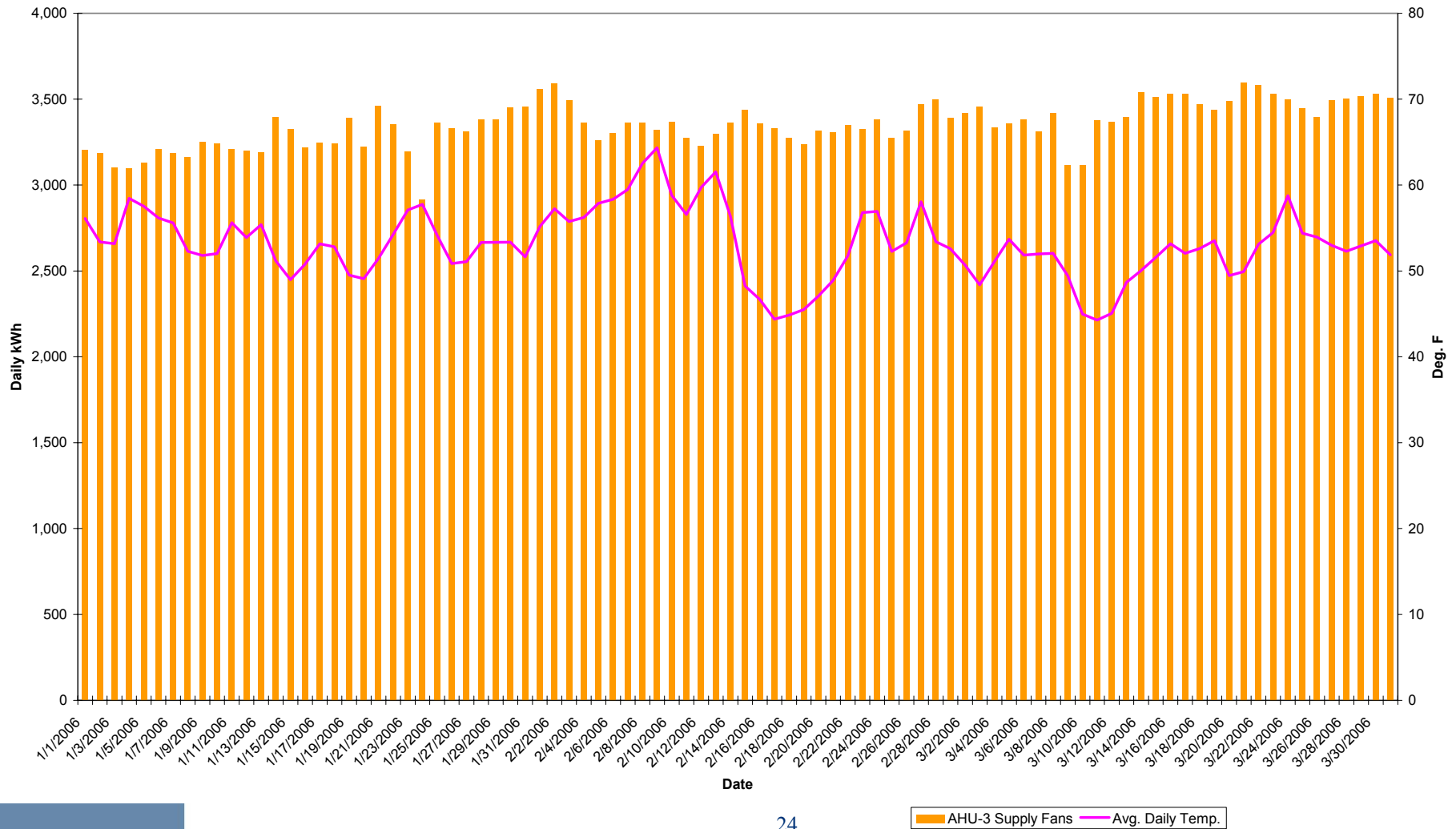
Tan Hall RCx Findings

- Chilled water and condenser water pumps operating in parallel instead of lead/lag
 - Balancing vales on each were closed down
 - Shut off one pump, rebalance flow and operate in lead/lag mode as intended
- Chiller outside air lockout temperature sequence not functioning
 - OAT set point also too high
 - Correct operation and lower set point 2 °F
- Leaky steam valve in AHU – caused simultaneous heating and cooling
- Savings: 654,000 kWh (14%), 90 kW, 10.5 M lbs steam (62%)
 - Estimated using bin analysis
- Cost reduction \$154,000 (19%), Payback 0.02 years

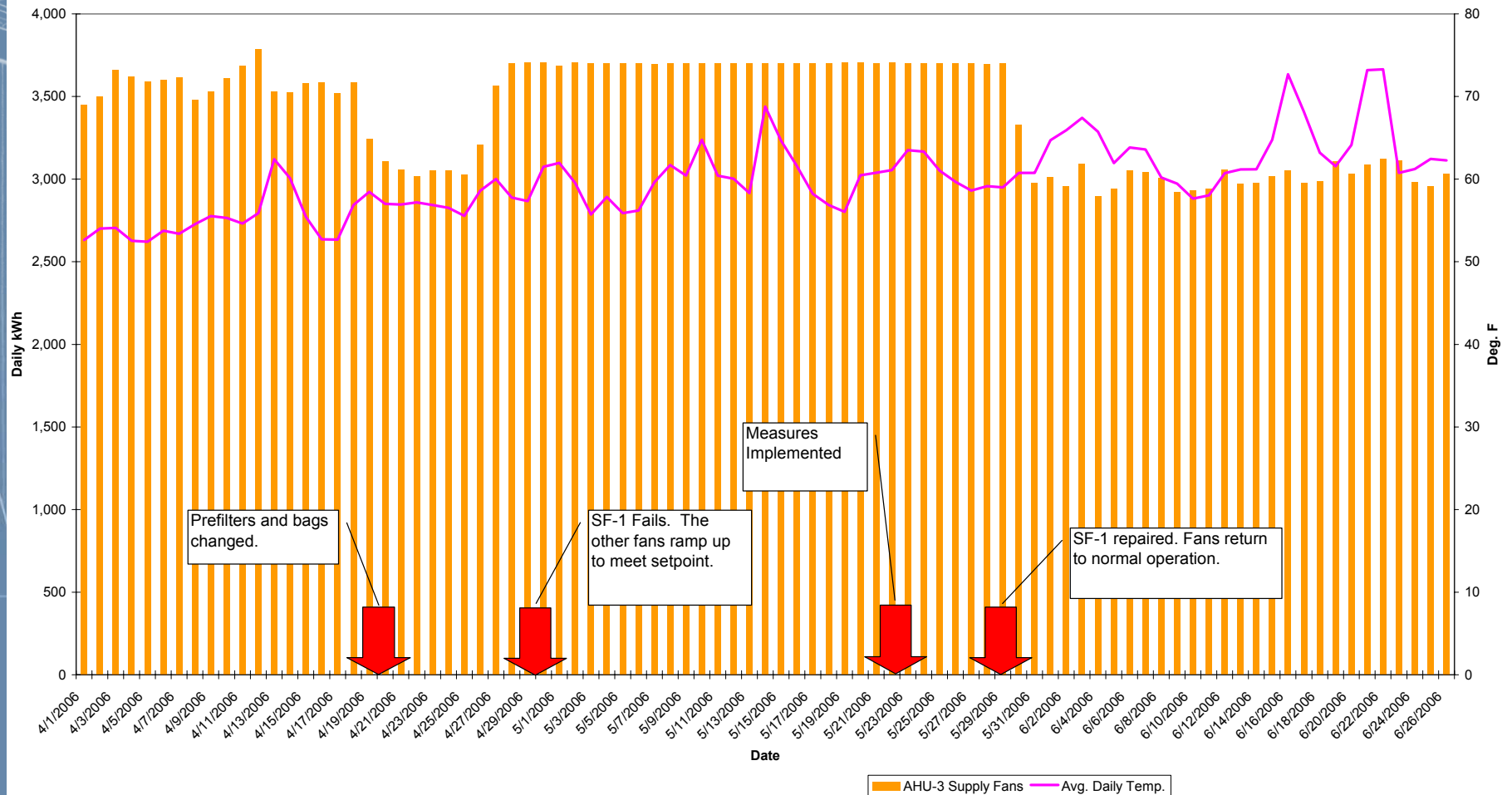
Tan Hall Affected Systems

System	Equipment	Affected by ECM?	Available Points
<u>Whole Building</u>		X	
	Main 480/277 Electric Meter		kW
	Main 220/110 Electric Meter		kW
	Main Steam Meter		lbs/hr
<u>Chilled Water System</u>		X	
	Chiller (VS)		kW
	Primary Chilled Water Pumps CHWP-1, CHWP-2 (CS)		Status
<u>Condenser Water System</u>		X	
	Condenser Water Pumps CDWP-1, CDWP-2 (CS)		Status
	Cooling Tower (CS, 2-speed)		Not Avail.
<u>AHU-3</u>		X	
	AHU-3 Supply Fans SF-1, SF-2, SF-3, SF-4 (CS)		S/S & Speed
	AHU-3 Exhaust Fans EF-1, EF-2, EF-3, EF-4 (CS)		S/S & Speed
	Terminal Boxes and Fume Hoods associated with AHU-3		NA
<u>AHU-1</u>			
	AHU-1 Chemical Storage AH-1, SE-1		Status
<u>AHU-2</u>			
	AHU-2 Chemical Storage AH-2, SE-2		Status
<u>Heating Water System</u>		X	
	Heat Exchanger HWC-1		
	Hot Water Pumps HHWP-1, HHWP-2		Status
<u>Lighting System</u>			
	Lighting Circuits		NA
<u>Plug Loads</u>			
	Plug Load Circuits		NA
<u>Domestic Water</u>			
	Domestic Water Pumps		NA

Tan Hall Diagnostics

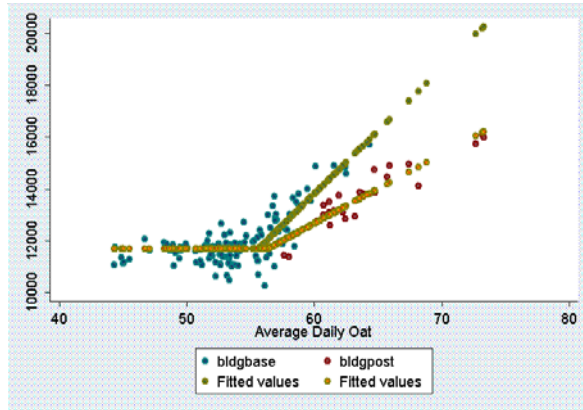


Tan Hall Diagnostics – cont.

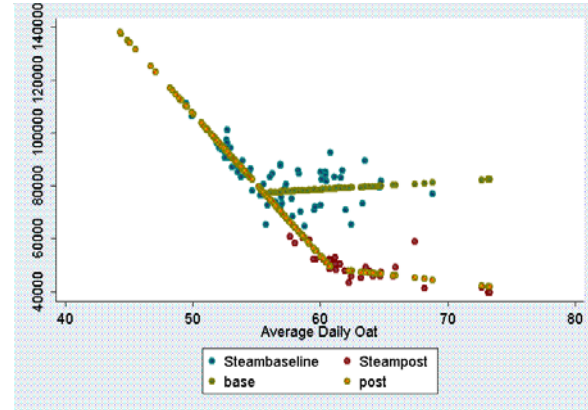


M&V Models: Tan Hall

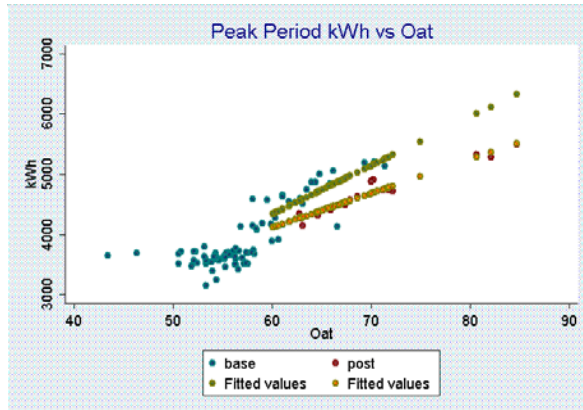
Whole Building Electric



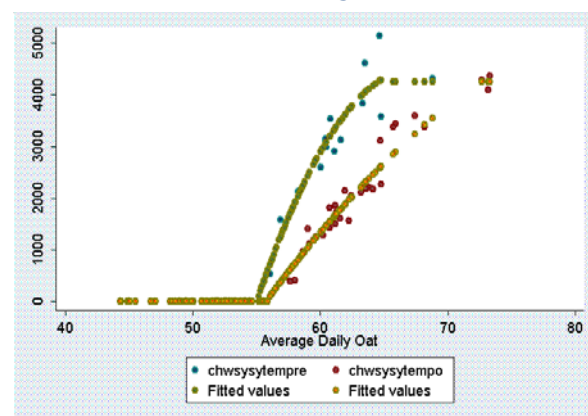
Whole Building Steam



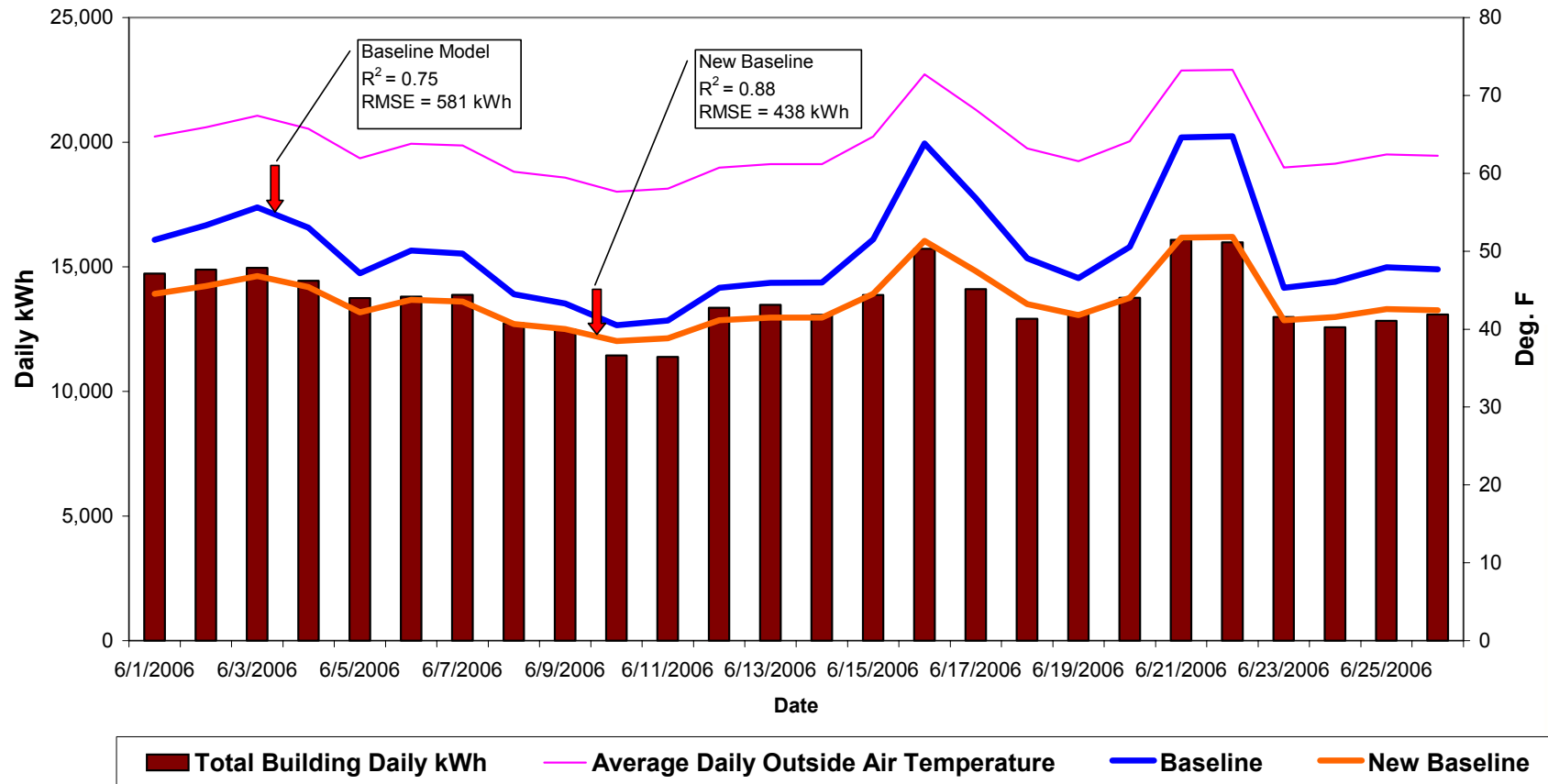
Peak Period Electric



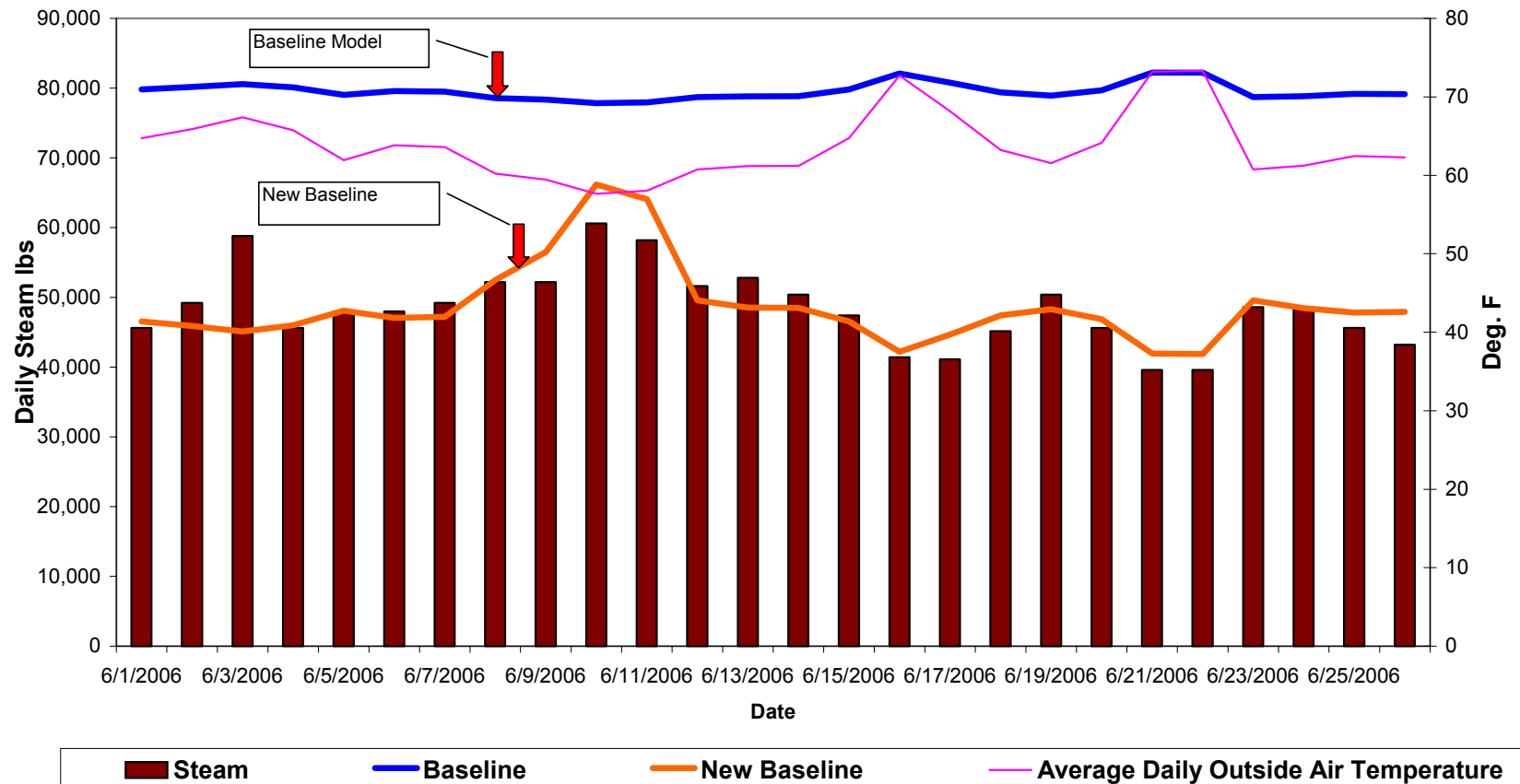
Chilled Water System Electric



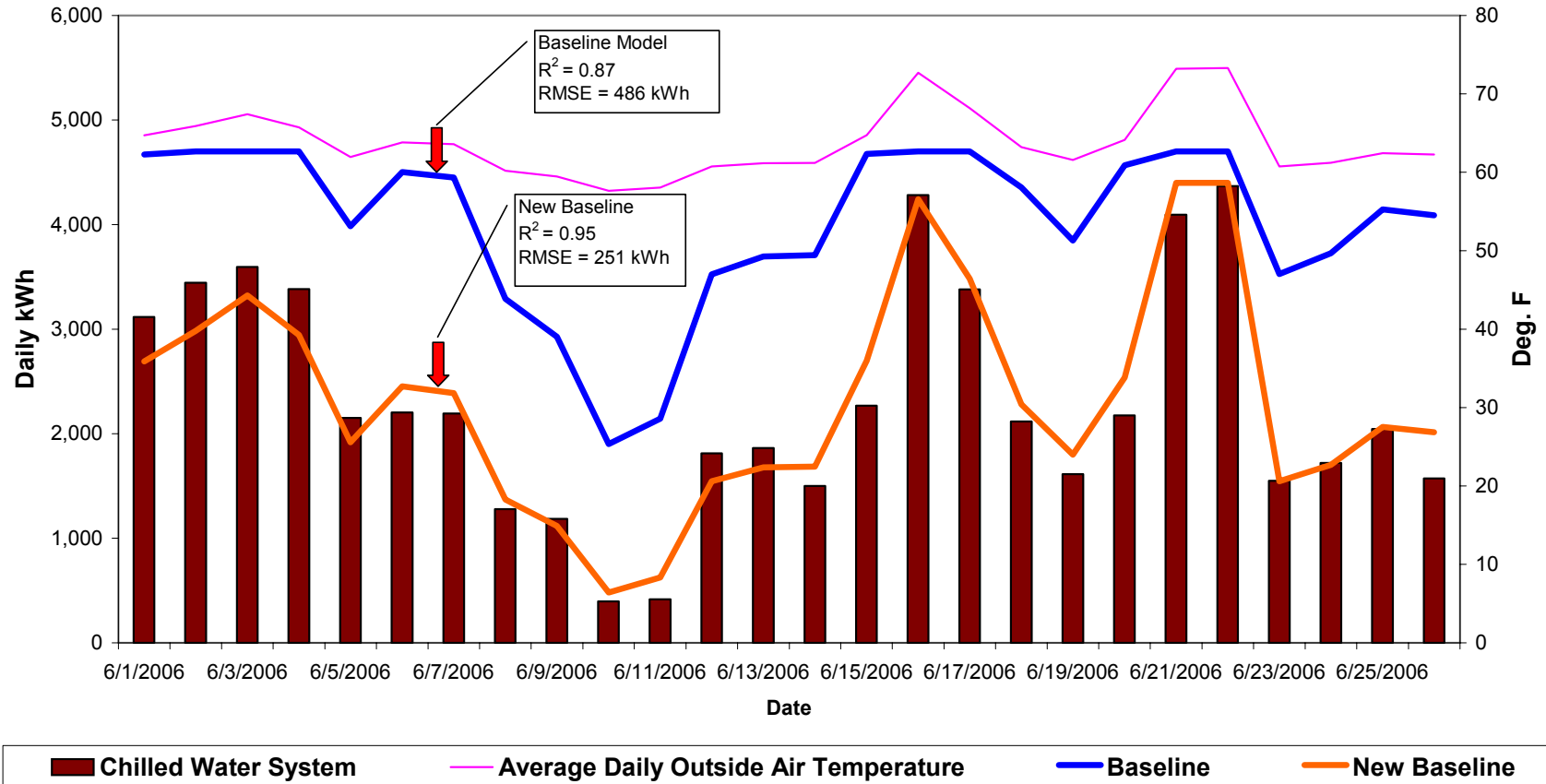
Tan Hall M&V: Whole-Building Electric



Tan Hall M&V: Whole-Building Steam



Tan Hall M&V: Chilled Water System



Tan Hall: Estimated vs. Verified Savings

Source	Estimated Savings*	Verified Savings**	
		Whole Building	CHW System
kWh	653,575	663,184	686,519
kW	91	69	
Lbs. Steam	10,543,991	5,995,232	

* based on engineering calculations

** based on baseline and post-installation measurements and TMY OAT data

Costs

Building	Metering Costs	MBCx Agent Costs	In-House Costs	Total
Soda Hall	\$ 4,442	\$ 62,160	\$ 51,087	\$ 117,689
Tan Hall	\$ 22,573	\$ 53,000	\$ 15,300	\$ 90,873

- Including all costs, project remains cost-effective:
 - Soda Hall: 1.7 year payback
 - Tan Hall: 0.7 year payback
- Added costs of metering hardware and software did not overburden project's costs
- In private sector – metering costs lower
 - Existing electric meters
 - Sophisticated BAS systems
 - MBCx approach should be viable

Discussion

- **Consider new approach:**
 - **Focus project resources on verified savings instead of estimated savings approach**
 - **More rigorous savings analysis, more reliable results**
 - **Install all low-cost measures**
 - **Estimate savings for only higher cost measures**
 - **Leave in place capability to track & tally savings**
 - **Diagnostic benefits of approach**
 - **Addresses savings persistence**
- **Barrier**
 - **Lack of understanding of M&V**
 - **M&V training required**

Conclusion

- Soda & Tan Hall projects showed technique to integrate M&V into RCx
- Technique as tools:
 - Diagnostic capability,
 - Verify savings, track energy use
- Other benefits
 - Persistence of RCx savings
 - Less uncertainty in savings
 - Establish new baselines for next project

Related Work

M&V Guidelines:

- Energy Valuation Organization's International Performance Measurement and Verification Protocol (IPMVP)
 - New 2007 release available now at: www.evo-world.org
- ASHRAE Guideline 14: www.ashrae.org
- California Commissioning Collaborative: Verification of Savings Project
 - Review current M&V methods within RCx projects
 - Recommend best practices for M&V in RCx
 - Disseminate results